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Nishida et al.

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(54) **SEMICONDUCTOR DEVICE, METHOD FOR INSTALLING HEAT DISSIPATION MEMBER TO SEMICONDUCTOR DEVICE, AND A METHOD FOR PRODUCING SEMICONDUCTOR DEVICE**

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See application file for complete search history.

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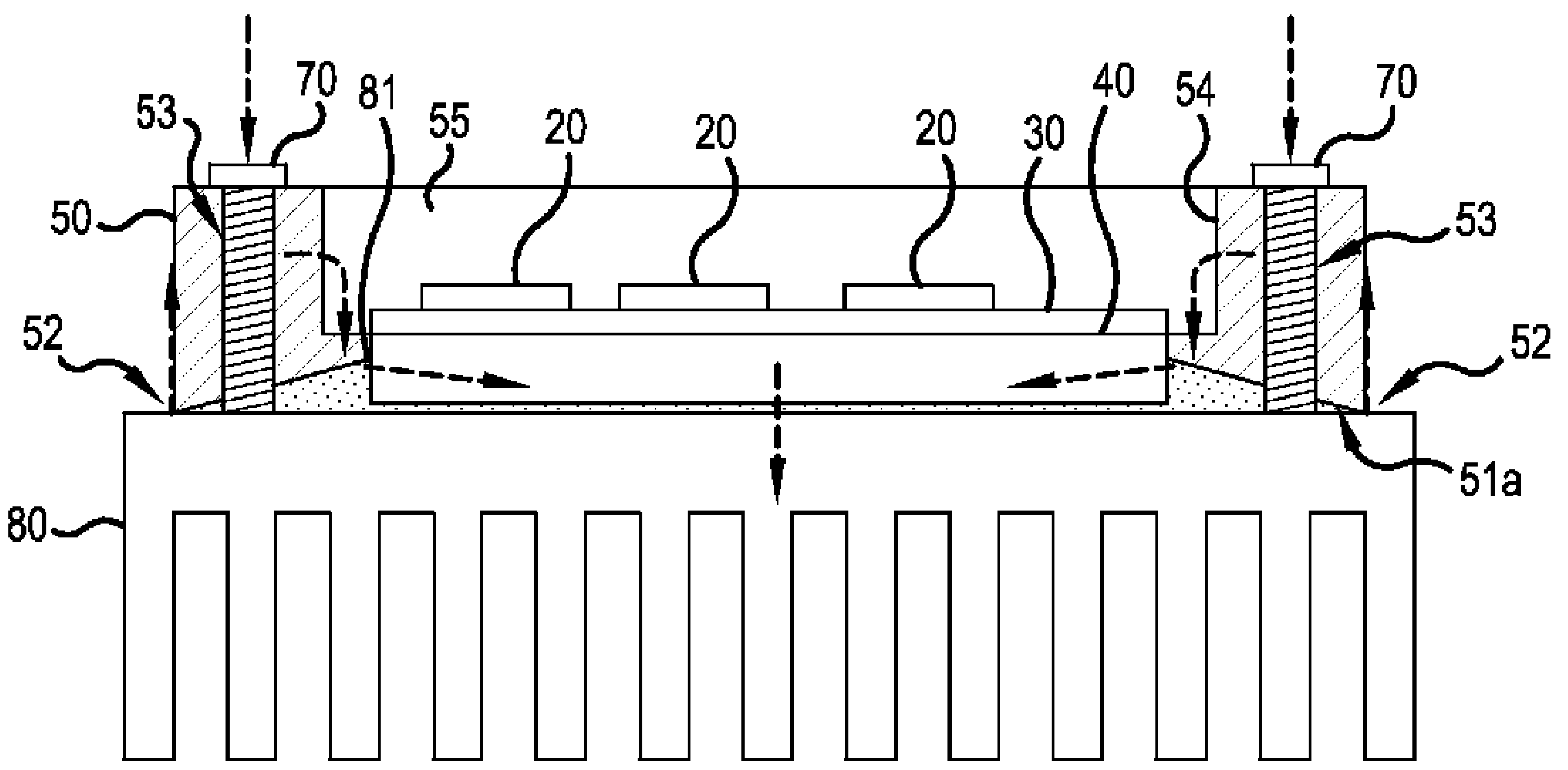
(57) **ABSTRACT**

A semiconductor device is fastened to a heat dissipation member such that a force directed downward acts from a metal substrate onto the heat dissipation member, with a rim portion of a storage region as a fulcrum with respect to the heat dissipation member. As a result, a heat conductive material can be spread into a thinner layer between the metal substrate and the heat dissipation member, improving the heat dissipation between the metal substrate and the heat dissipation member.

20 Claims, 5 Drawing Sheets



(51) **Int. Cl.**

H01L 21/56	(2006.01)
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H01L 23/13	(2006.01)
H01L 23/36	(2006.01)
H01L 23/373	(2006.01)
H01L 23/049	(2006.01)
H01L 23/498	(2006.01)
H01L 25/07	(2006.01)
H01L 23/00	(2006.01)

(52) **U.S. Cl.**

CPC ***H01L 23/13*** (2013.01); ***H01L 23/3121*** (2013.01); ***H01L 23/36*** (2013.01); ***H01L 23/3735*** (2013.01); *H01L 23/049* (2013.01); *H01L 23/49811* (2013.01); *H01L 24/45* (2013.01); *H01L 25/072* (2013.01); *H01L 2224/45124* (2013.01); *H01L 2224/48137* (2013.01); *H01L 2224/48227* (2013.01); *H01L 2924/19107* (2013.01); *H01L 2924/3511* (2013.01)

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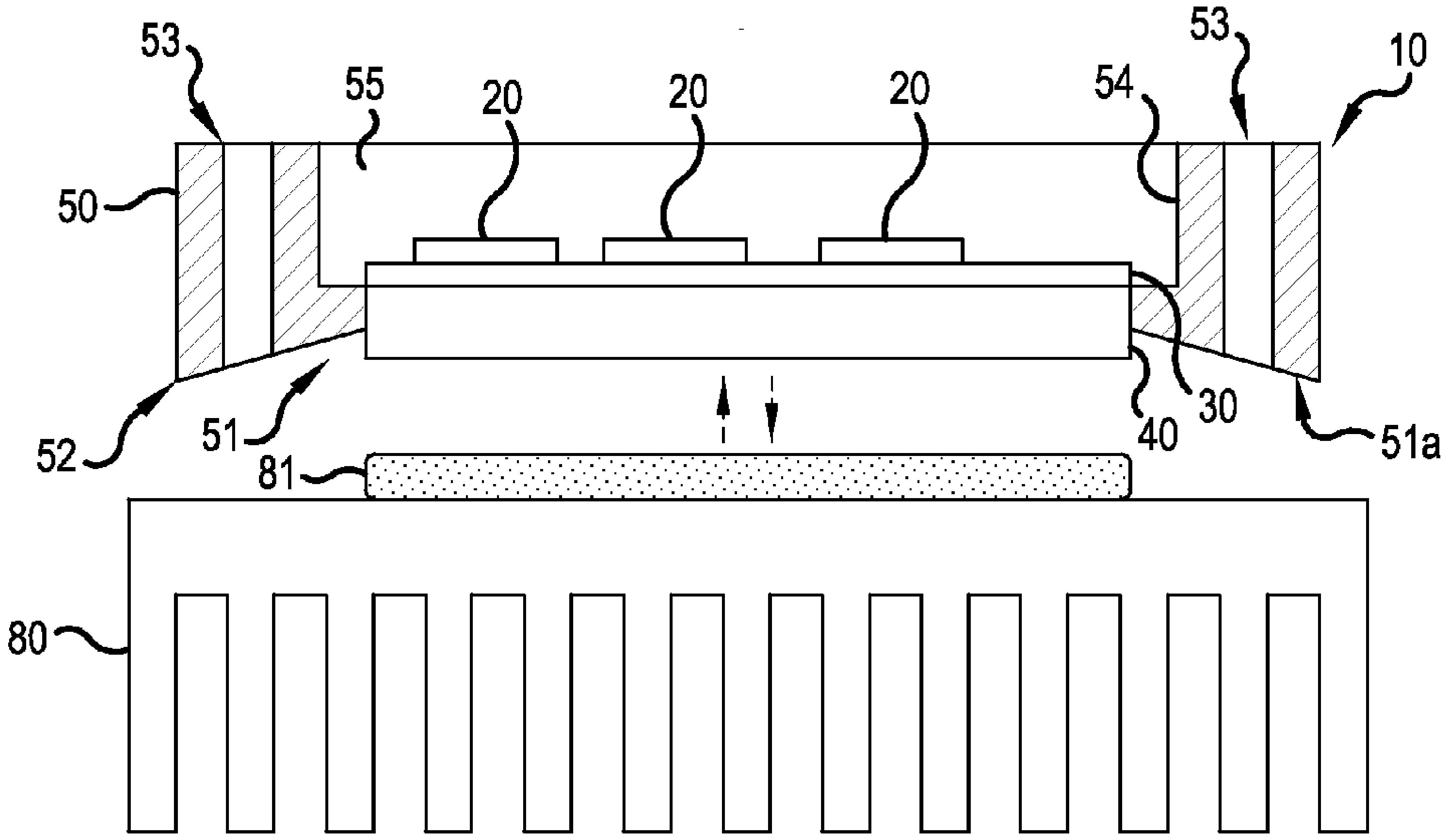

FIG.1A

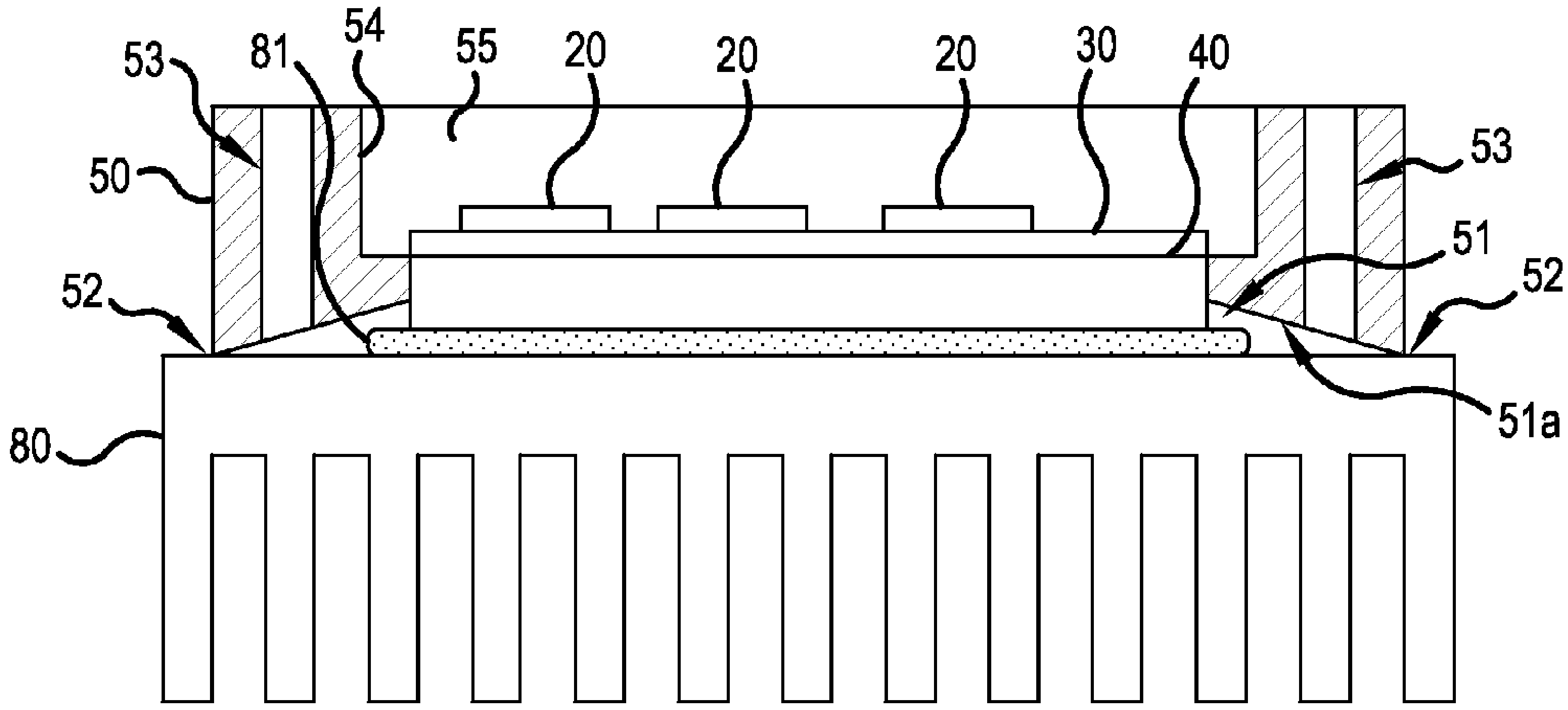

FIG.1B

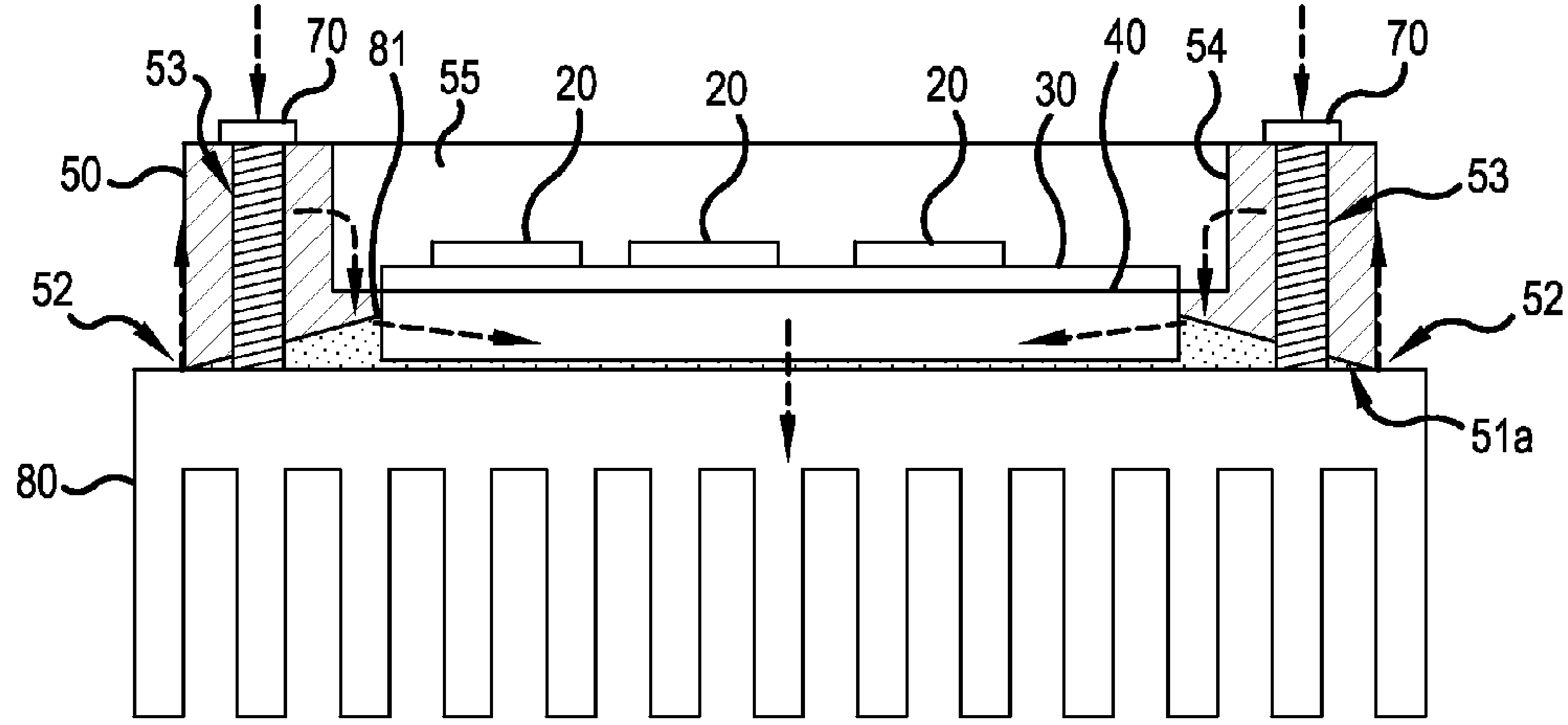

FIG.1C

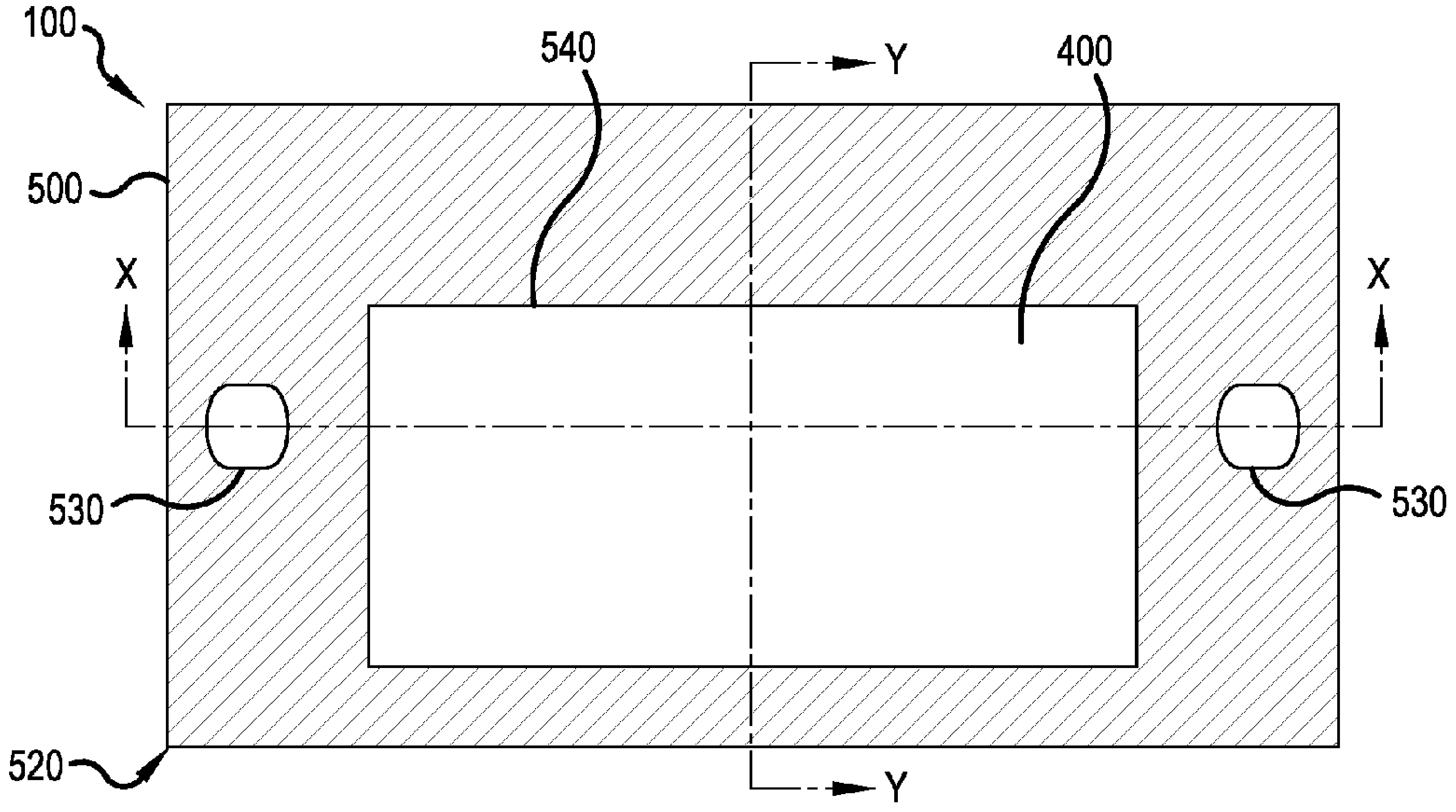

FIG.2A

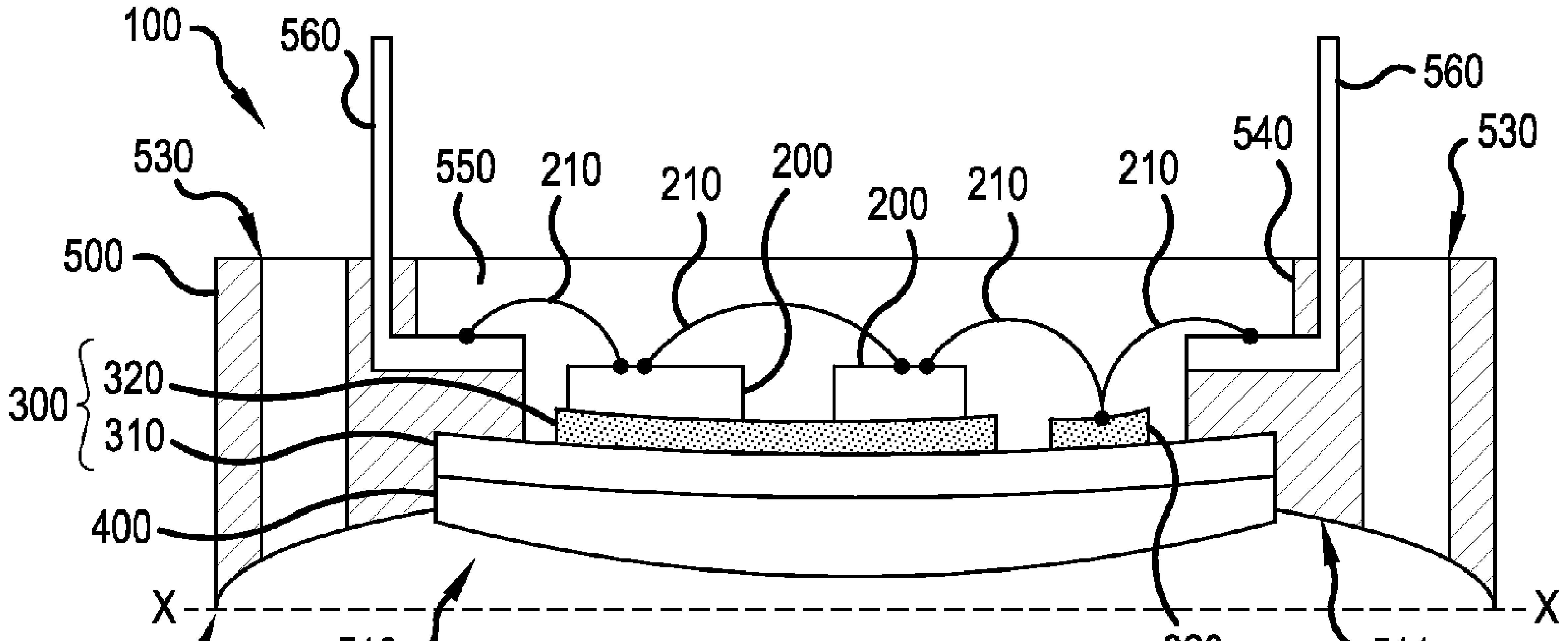

FIG.2B

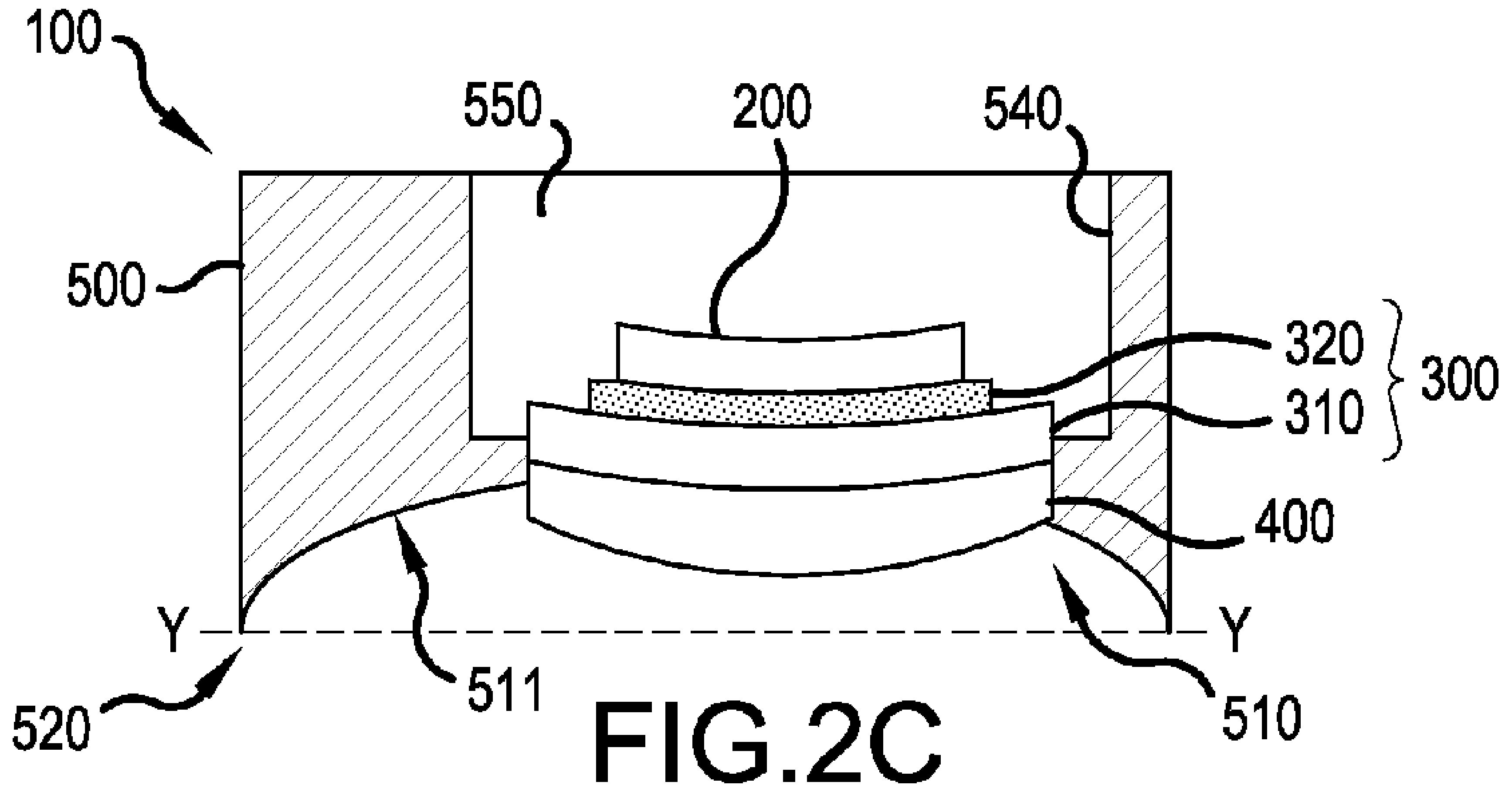

FIG.2C

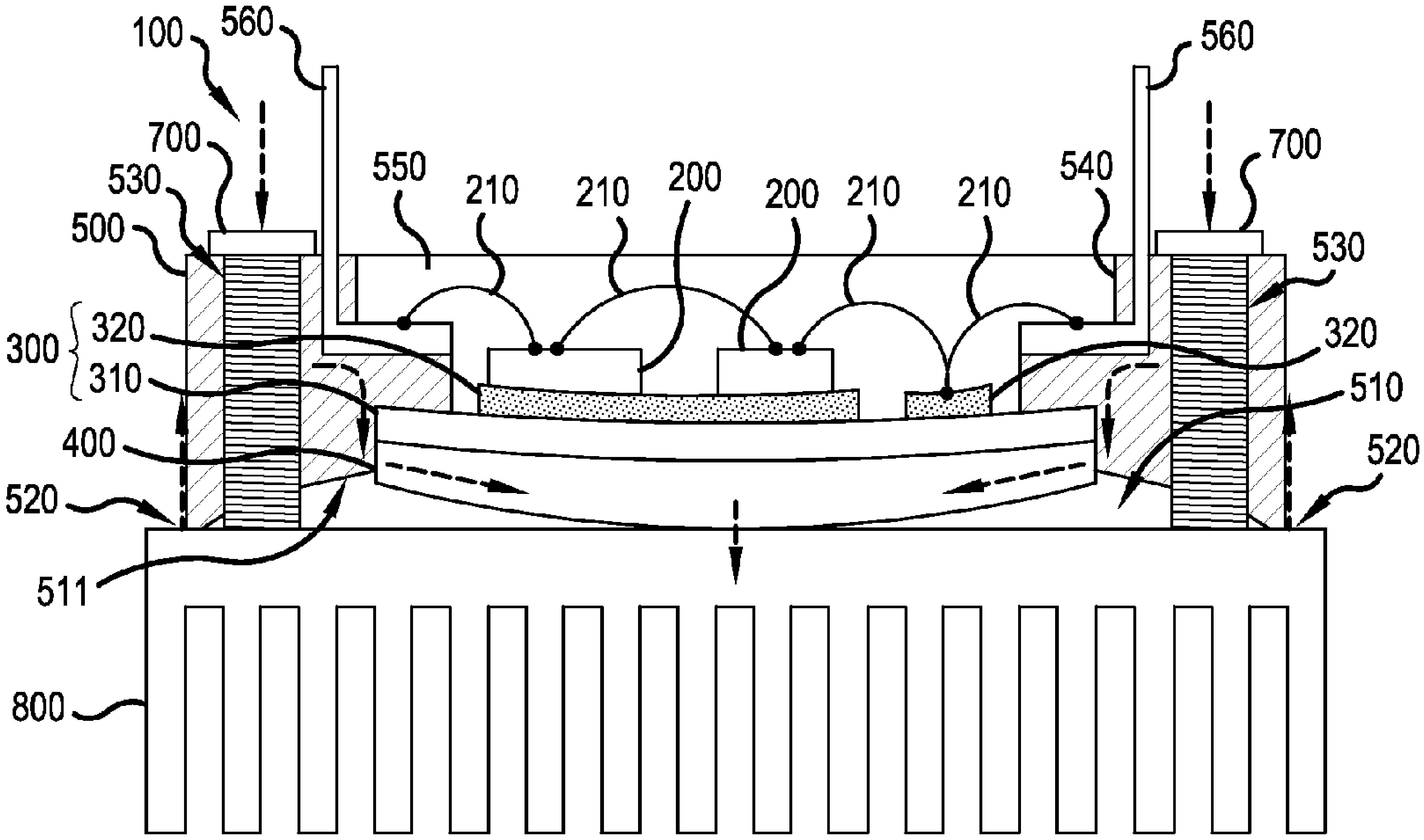
100
560
560
700
530
500
550
210
210
200
200
210
210
540
700
530
300
320
310
320
510
400
520
520
511
800

FIG.3A

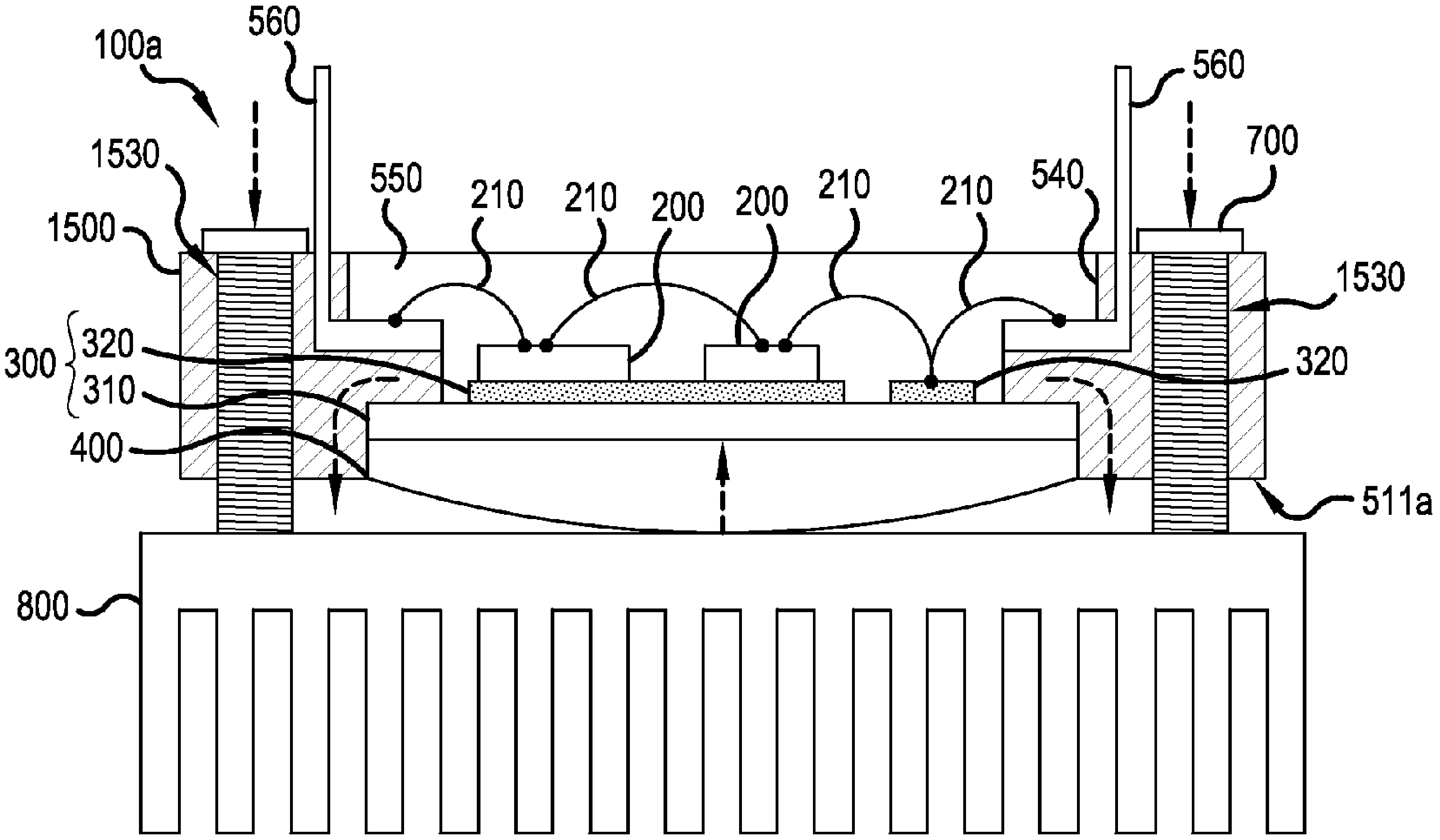
100a
560
560
1530
1500
550
210
210
200
200
210
210
540
700
1530
300
320
310
320
400
511a
800

FIG.3B

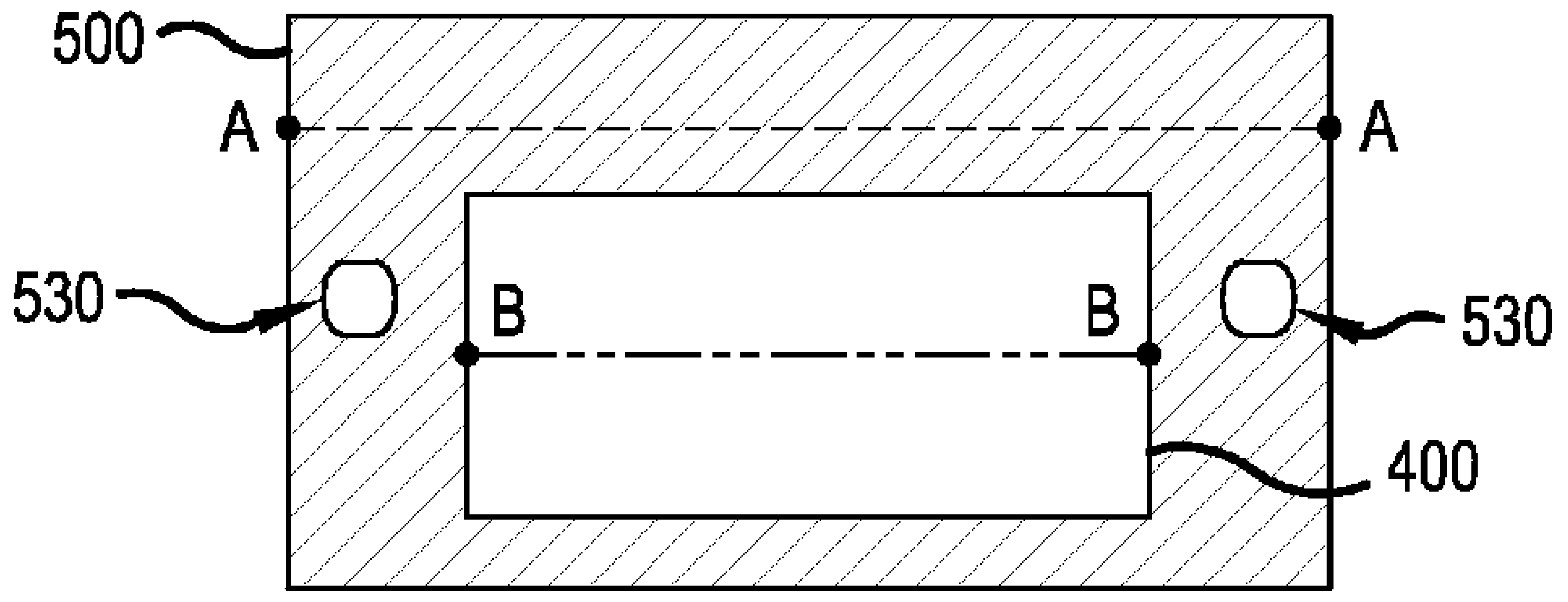

FIG.4A

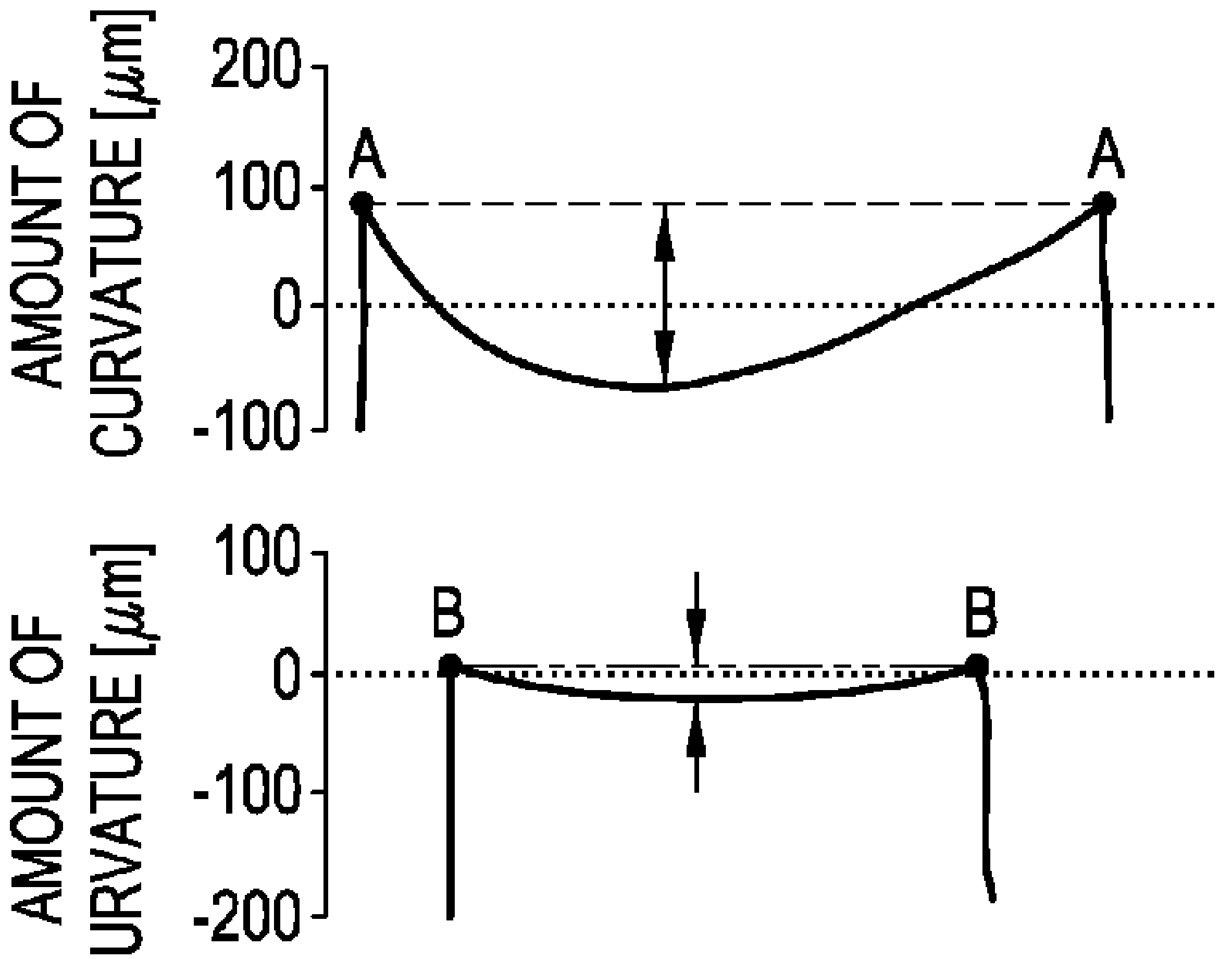

FIG.4B

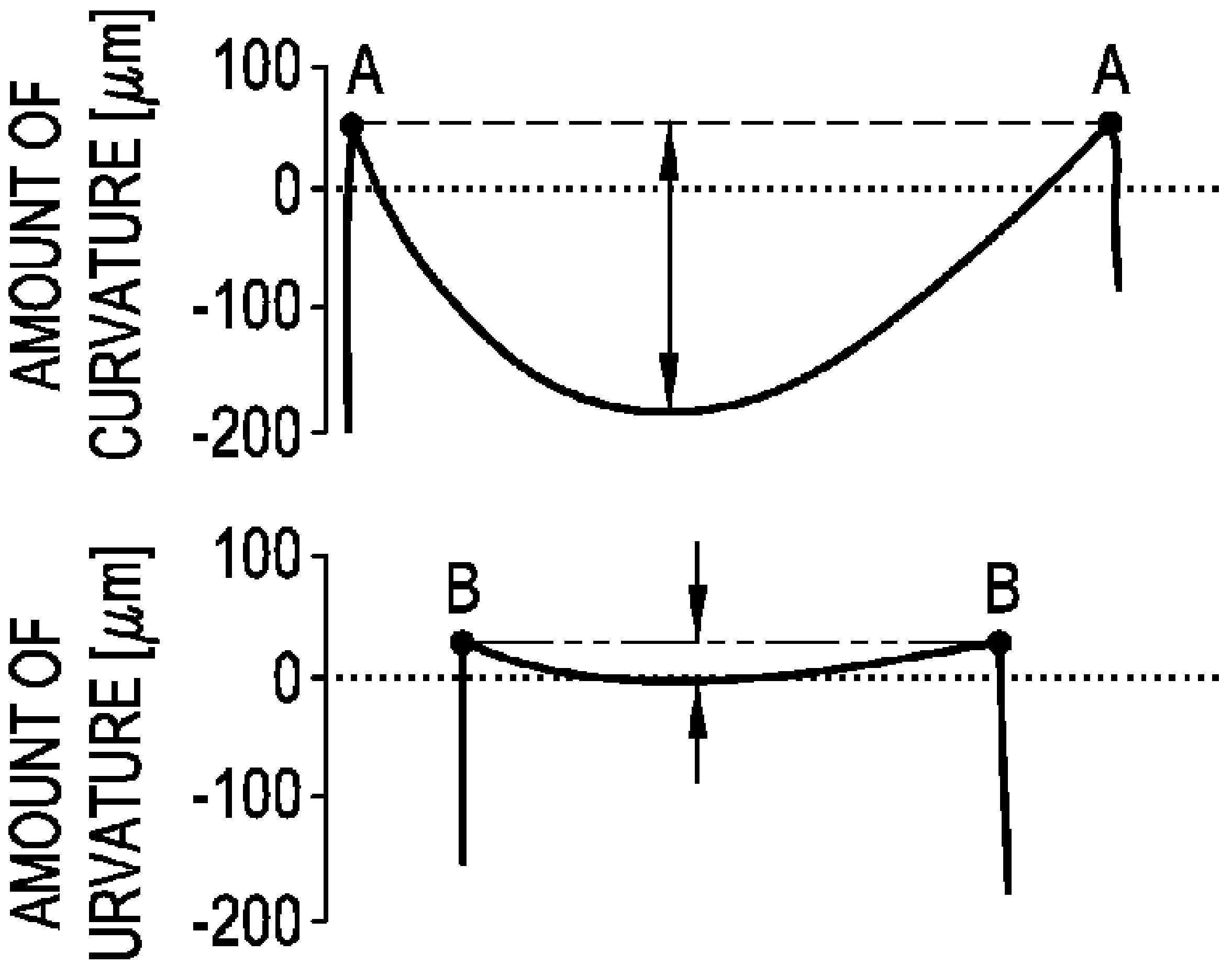

FIG.4C

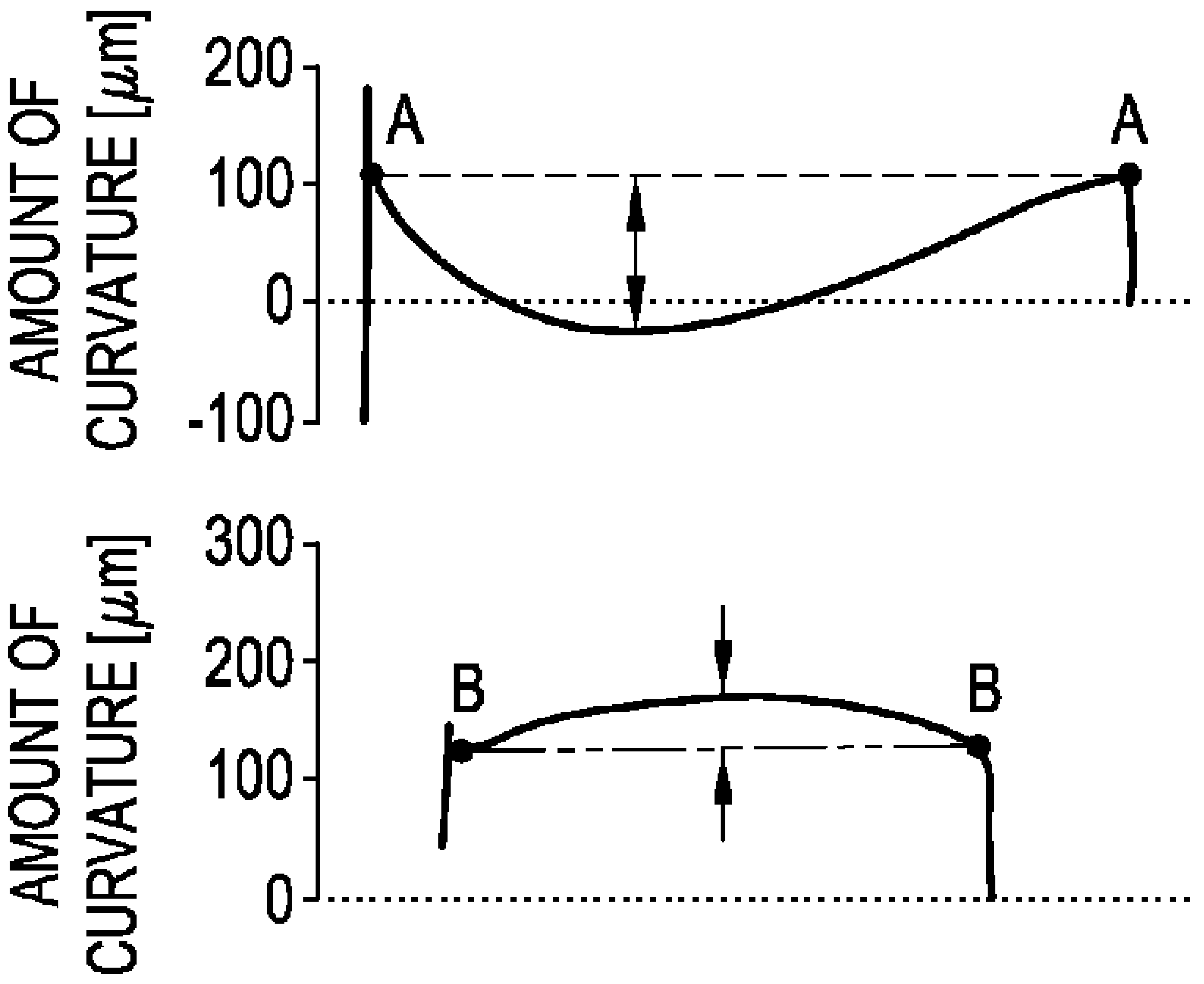

FIG.4D

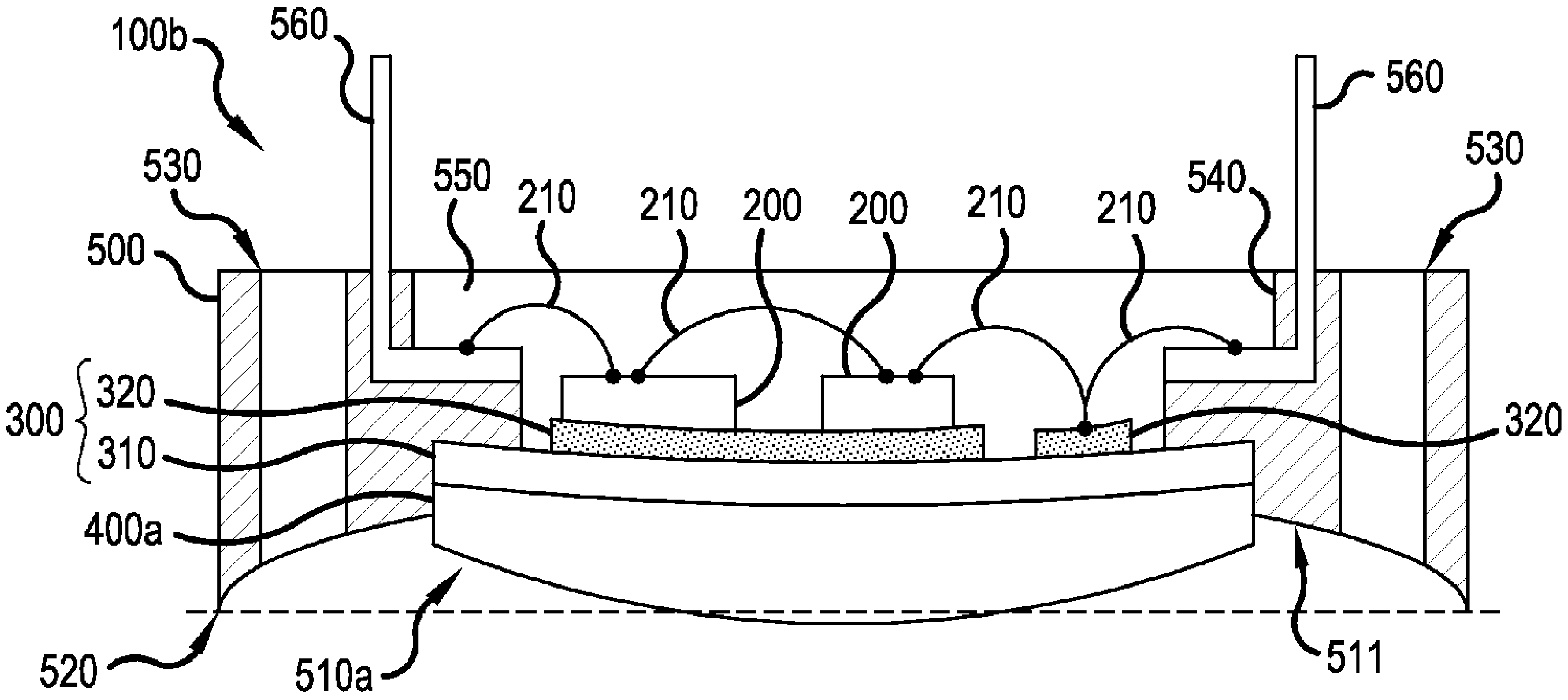
100b
560
560
530
530
500
550
210
210
200
200
210
210
540
300
320
310
320
400a
520
510a
511

FIG.5A

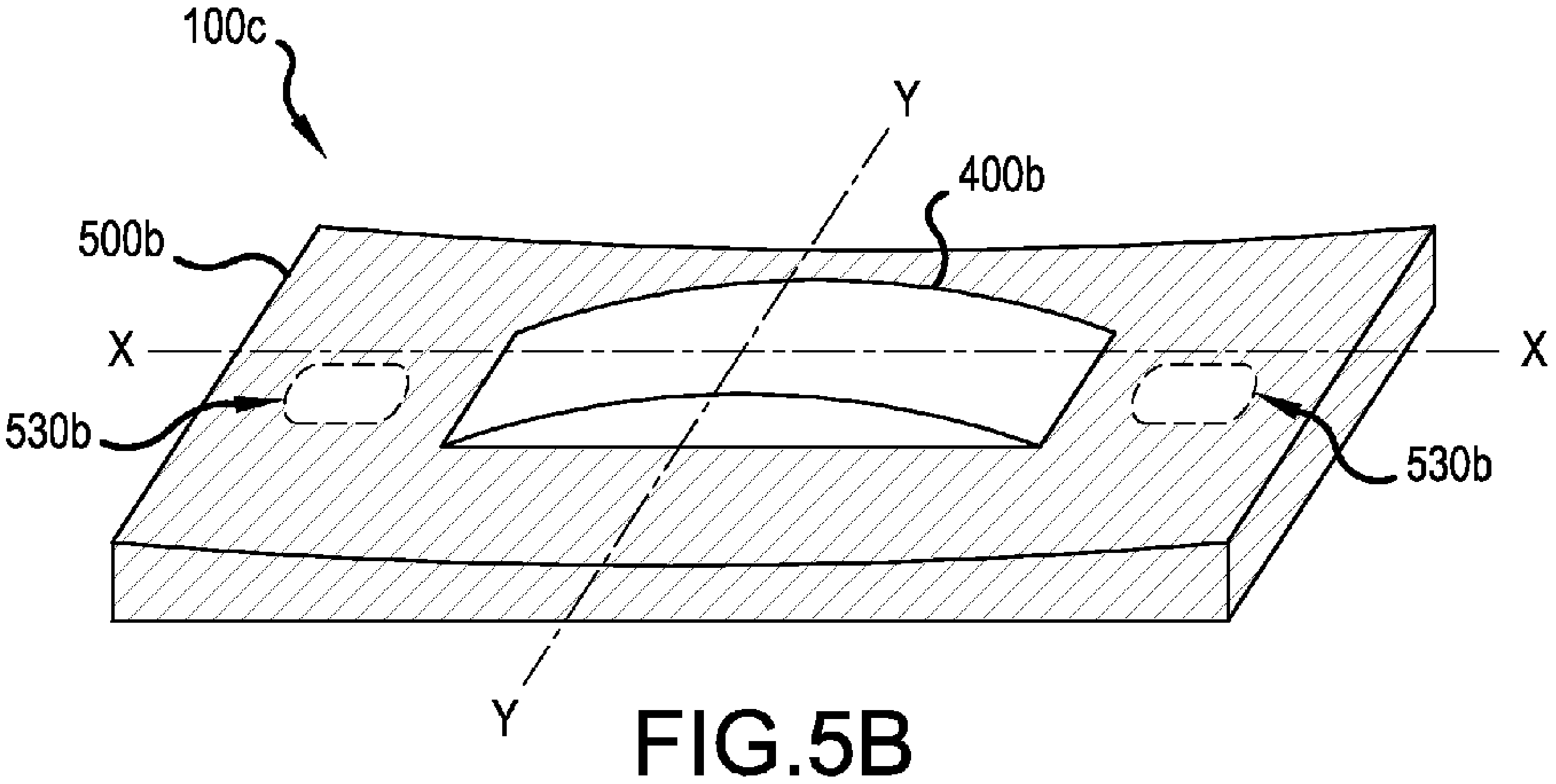
100c
Y
400b
500b
X
X
530b
530b
Y

FIG.5B

SEMICONDUCTOR DEVICE, METHOD FOR INSTALLING HEAT DISSIPATION MEMBER TO SEMICONDUCTOR DEVICE, AND A METHOD FOR PRODUCING SEMICONDUCTOR DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of International Application No. PCT/JP2013/071785, filed on Aug. 12, 2013, and is based on and claims priority to Japanese Patent Application No. JP 2012-201775, filed on Sep. 13, 2012. The disclosure of the Japanese priority application and the PCT application in their entirety, including the drawings, claims, and the specification thereof, are incorporated herein by reference.

BACKGROUND

Field of the Invention

Embodiments of the present invention relate to a semiconductor device, a method for installing a heat dissipation member to the semiconductor device, and a method for producing the semiconductor device.

Discussion of the Background

A semiconductor module (semiconductor device) such as a power conversion element mounted with a power semiconductor chip has a heat dissipation member such as a heat dissipation fin placed on a metal substrate of the semiconductor module, so that heat generated from the semiconductor chip is released by the heat dissipation member (see Japanese Patent Application Publication No. 2004-363521 ("Patent Document 1"), for example). Such a configuration can prevent the increase of the temperature of the semiconductor module.

A heat conductive material such as heat conductive grease is applied to the heat dissipation fin or the metal substrate of the semiconductor module prior to placing the heat dissipation fin on the semiconductor module. The heat conductive material is composed of an organic substance, and heat dissipation of the heat conductive material weakens as the coating thickness of the material becomes excessive. For this reason, the heat conductive material needs to be applied in a layer as thin as possible. By fastening the heat dissipation fin to the metal substrate of the semiconductor module with a screw or the like after the application of the heat conductive material, a force to reduce the thickness of the heat conductive material can be generated at the center of the heat dissipation fin immediately below the semiconductor element. As a result, the distance between the metal substrate and the heat dissipation fin decreases, thereby spreading the heat conductive material into a thin layer, further improving the ability to release heat generated from the semiconductor element (see Japanese Patent Application Publication No. 2000-058727 ("Patent Document 2"), for example).

In addition to using the technology disclosed in Patent Document 2 in which the thickness of the heat conductive material is reduced by changing the shape of the metal substrate (metal base) in the thickness direction, application of a heat conductive material is possible by controlling the shape and thickness of a metal substrate using a metal mask.

Patent Document 2, however, needs to form projections, mounting holes, and the like on the metal base in order to change the shape of the metal base in the thickness direction, and needs to prepare a mask even when using a metal mask.

Forming projections, mounting holes and the like and preparing a mask as described above involve a lot of effort, and thus lead to an increase in production cost.

SUMMARY

Embodiments of the present invention provide a semiconductor device having a configuration different from those described in the foregoing patent documents and thus having improved heat dissipation, a method for installing a heat dissipation member to such a semiconductor device, and a method for producing such a semiconductor device.

An embodiment of the present invention provides a semiconductor device which has a semiconductor element and on which a heat dissipation member is to be placed, the semiconductor device comprising: a circuit board having the semiconductor element placed on one of principal surfaces thereof; a metal substrate placed on the other principal surface of the circuit board; and a storage member that has a storage region having a concave principal surface and an opening which is disposed on the inside of the concave principal surface to store the circuit board therein with the metal substrate protruding from the concave principal surface, and screw holes that are opened in the concave principal surface to allow passage of screw members that are screwed to the heat dissipation member which is placed in such a manner as to face the metal substrate of the stored circuit board with a heat conductive material therebetween.

An embodiment of the present invention provides a method for installing a heat dissipation member to such a semiconductor device, and a method for producing such a semiconductor device.

According to this semiconductor device, the method for installing a heat dissipation member to the semiconductor device, and the method for producing the semiconductor device, heat dissipation of the semiconductor device can be improved.

The above and other objects, features, and advantages of the present invention will become apparent from the following description associated with the accompanying drawings which illustrate the embodiments preferred as examples of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A, **1**B, and **1**C are diagrams for explaining a semiconductor device according to a first embodiment and a method for installing a heat dissipation member to the semiconductor device.

FIGS. **2**A, **2**B, and **2**C are diagrams for explaining a semiconductor device according to a second embodiment.

FIGS. **3**A and **3**B are diagrams for explaining a method for installing a heat dissipation fin to the semiconductor device according to the second embodiment.

FIGS. **4**A, **4**B, **4**C, and **4**D are diagrams for explaining a method for producing the semiconductor device according to the second embodiment.

FIGS. **5**A and **5**B are diagrams for explaining another semiconductor device according to the second embodiment.

DESCRIPTION OF ILLUSTRATED EMBODIMENTS

Embodiments of the present invention are now described hereinafter with reference to the drawings.

First Embodiment

FIG. **1** is a diagram for explaining a semiconductor device according to a first embodiment and a method for installing a heat dissipation member to the semiconductor device.

A semiconductor device **10** has a semiconductor element **20**. The semiconductor device **10** is placed on a heat dissipation member **80** and used. When placing the semiconductor device **10** on the heat dissipation member **80**, a heat conductive material **81** is spread evenly into a thin layer between a metal substrate **40** below the semiconductor element **20** and the heat dissipation member **80**. Owing to such a configuration of the semiconductor device **10**, heat of the semiconductor element **20** can be transmitted from the metal substrate **40** to the heat dissipation member **80**, improving the thermal conductivity of the semiconductor device **10**.

As shown in FIG. **1**A, this semiconductor device **10** has a circuit board **30** having the semiconductor element **20** placed on one of its principal surfaces, and the metal substrate **40** placed on the other principal surface of the circuit board **30**.

The semiconductor device **10** also has a storage member **50** for accommodating the circuit board **30**. The storage member **50** is a frame-like (O-shaped) or rim-like member and has a storage region **51** having a concave principal surface **51***a* (the lower side of the diagram) and an opening **54** disposed on the inside of this concave principal surface **51***a*. The storage member **50** further has screw holes **53** passing between the concave principal surface **51***a* and a principal surface facing the principal surface **51***a* (the upper side of the diagram). The circuit board **30** is stored in the opening **54**, with the metal substrate **40** protruding from the concave principal surface **51***a*. Screw members **70** (described hereinafter) are inserted into the screw holes **53** and screwed to the heat dissipation member **80** that is placed facing the metal substrate **40** of the stored circuit board **30** with the heat conductive material **81** therebetween. The concave principal surface **51***a* is configured by a flat surface or a curved surface that is inclined with respect to the principal surface facing the principal surface **51***a* (the upper side of the diagram), and is formed in such a manner that a rim portion **52** disposed outside the screw holes **53** in the storage region **51** protrudes toward the heat dissipation member **80**. The screw holes **53** are formed, with the axes thereof situated substantially perpendicular to the upper surface of the storage member **50**. Note that the circuit board **30**, which is stored in the storage region **51** of the storage member **50**, is sealed together with the semiconductor element **20** with resin **55**.

Next is described a method for installing the semiconductor device **10** of such a configuration to the heat dissipation member **80**. First, a predetermined amount of the heat conductive material **81** is disposed in a region of the heat dissipation member **80** with which the metal substrate **40** comes into contact (FIG. **1**A). Note that the heat conductive material **81** may be disposed in the region near the metal substrate **40**. The heat conductive material **81** is heat conductive grease (a thermal compound) or the like that is generally used.

The heat dissipation member **80** with the heat conductive material **81** and the semiconductor device **10** are then fixed to each other. In so doing, the heat dissipation member **80** is supported by the rim portion **52** of the storage region **51** of the storage member **50** of the semiconductor device **10**. The heat conductive material **81** is spread between the heat dissipation member **80** and the metal substrate **40** of the semiconductor device **10** (FIG. **1**B).

The screw members **70** are inserted into the screw holes **53** of the storage member **50** of the semiconductor device **10** and screwed to the heat dissipation member **80**, to fasten the semiconductor device **10** to the heat dissipation member **80** (FIG. **1**C).

In the semiconductor device **10** at this moment, a force is applied to the center of the metal substrate **40**, with the rim portion **52** of the storage region **51** as a fulcrum with respect to the heat dissipation member **80**, and a force that is directed downward in the diagram acts from the metal substrate **40** onto the heat dissipation member **80**. The heat conductive material **81** can be spread into a thin layer as the distance between the metal substrate **40** and the heat dissipation member **80** decreases as described above. As a result, heat dissipation between the metal substrate **40** and the heat dissipation member **80** improves. Moreover, the heat conductive material **81** spreads outside the metal substrate **40** and fills the periphery of the metal substrate **40**. This leads to an increase in air tightness of the periphery of the metal substrate **40**, inhibiting bubbles and the like from being mixed therein and preventing the deterioration of the heat dissipation.

The semiconductor device **10** described above has the semiconductor element **20**, the circuit board **30** having the semiconductor element **20** placed on one of its principal surfaces, the metal substrate **40** placed on the other principal surface of the circuit board **30**, and the storage member **50** that has the storage region **51** in which the principal surface **51***a* thereof configures a concave opening, and the screw holes **53**. In the semiconductor device **10**, the circuit board **30** is stored in the storage region **51** of the storage member **50**, with the metal substrate **40** protruding from the concave principal surface **51***a*, and the stored circuit board **30** is sealed together with the semiconductor element **20** with the resin **55**. The metal substrate **40** and the heat dissipation member **80** are fixed to each other by the heat conductive material **81** therebetween, and the screw members **70** are inserted into the screw holes **53** of the storage member **50** and screwed to the heat dissipation member **80**, to fasten the semiconductor device **10** to the heat dissipation member **80**.

By fastening the semiconductor device **10** to the heat dissipation member **80** as described above, a force from the storage member **50** is applied to the center of the metal substrate **40** in the semiconductor device **10**, with the rim portion **52** of the storage region **51** as a fulcrum, and a force that is directed downward in the diagram acts from the metal substrate **40** onto the heat dissipation member **80**. As a result, the heat conductive material **81** can be spread into a thin layer between the metal substrate **40** and the heat dissipation member **80**, improving the heat dissipation between the metal substrate **40** and the heat dissipation member **80**. Moreover, the heat conductive material **81** that is spread to the outside of the metal substrate **40** fills the periphery of the metal substrate **40**. This leads to an increase in air tightness of the periphery of the metal substrate **40**, inhibiting bubbles and the like from being mixed therein and preventing the deterioration of the heat dissipation. Heat dissipation of the semiconductor device **10** to which the heat dissipation member **80** is installed in this manner can be improved.

Second Embodiment

In the second embodiment, the semiconductor device of the first embodiment is described with more specific examples.

FIG. **2**A is a plan view showing the back of a semiconductor device **100** (the side to which a heat dissipation fin is installed), FIG. **2**B a cross-sectional diagram of the semiconductor device **100**, taken along a dashed line X-X of FIG. **2**A, and FIG. **2**C a cross-sectional diagram of the semiconductor device **100**, taken along a dashed line Y-Y of FIG. **2**A.

The semiconductor device **100** has a plurality of semiconductor elements **200**, a circuit board **300** on which the plurality of semiconductor elements **200** are placed, and an aluminum base substrate **400** placed on the circuit board **300**.

The circuit board **300** is configured by an insulating substrate **310** and a circuit layer **320** on the insulating substrate **310**, which is a circuit pattern formed from a metal foil piece made of copper or the like. The semiconductor device **100** also has a resin case **500** (i.e. storage member) having a storage region **510** with a concave principal surface **511** and an opening **540** and having external terminals **560** formed above the storage region **510**. The principal surface **511** of the resin case **500** is depressed inward into the shape of a funnel or a ball. Note that illustration of the external terminals **560** is omitted in FIG. **2**C. The resin case **500** is composed of, for example, glass-reinforced epoxy resin or PPS (polyphenylene sulfide) resin. In addition, screw holes **530** are formed between a rim portion **520** of the resin case **500** and the opening **540**. The screw holes **530** are formed facing each other with the opening **540** therebetween. The diameter of the screw holes **530** is greater than that of screws **700**. It is desired that each screw hole **530** be shaped into a rectangle or an oval that is elongated in the direction connecting the two screw holes **530** (the direction of the dashed line X-X). The number of the screw holes **530** does not have to be two; thus, three or more of the screw holes **530** may be formed, if need be. In this resin case **500**, the circuit board **300** is stored in the storage region **510** with the base substrate **400** positioned downward in the diagram. The semiconductor elements **200** and the circuit layer **320** on the circuit board **300** stored as described above are electrically connected to the external terminals **560** of the resin case **500** by aluminum wires **210** and sealed with sealing resin **550**. Soft gel-type resin, for example, can be used as the sealing resin **550**. When using gel-type resin as the sealing resin **550**, a lid with high hardness such as epoxy resin should be used to cover the gel-type resin. When sealing with the sealing resin **550**, resin with high hardness such as epoxy resin can be casted.

Note that the base substrate **400** has a shape that is pointed downward in the diagram (into the shape of a mound), with its bottom portion (apex portion) being convexed downward, as shown in FIGS. **2**B and **2**C. For this reason, the level of the apex portion of the base substrate **400** is set in such a manner that the apex portion is accommodated completely in the concave storage region **510** of the resin case **500**.

A method for installing a heat dissipation fin **800** to such a semiconductor device **100** is now described with reference to FIGS. **3**A and **3**B. FIGS. **3**A and **3**B are diagrams for explaining a method for installing a heat dissipation fin to the semiconductor device according to the second embodiment.

Note that FIG. **3**A shows how the heat dissipation fin **800** is installed to the semiconductor device **100** according to the second embodiment, while FIG. **3**B shows how the heat dissipation fin **800** is installed to a semiconductor device **100***a*. Illustration of a heat conductive material to be disposed between the base substrate **400** and the heat dissipation fin **800** is omitted in FIGS. **3**A and **3**B.

First of all, a predetermined amount of heat conductive grease (not shown) is disposed as the heat conductive material at substantially the central region on the fixing side of the semiconductor device **100** near the heat dissipation fin **800**, and then the semiconductor device **100** is placed on the heat dissipation fin **800** in such a manner that the base substrate **400** faces the heat conductive grease.

The screws **700** are inserted into the screw holes **530** of the resin case **500** of the semiconductor device **100** and screwed to the heat dissipation fin **800**, to fasten the semiconductor device **100** to the heat dissipation fin **800** (FIG. **3**A).

In so doing, in the semiconductor device **100**, when a force that is directed downward in the diagram is applied by the screws **700** screwed to the heat dissipation fin **800**, the force acts on the center of the base substrate **400**, with the rim portion **520** of the storage region **510** supporting the heat dissipation fin **800** as a fulcrum. Consequently, a force that is directed downward in the diagram acts from the base substrate **400** onto the heat dissipation fin **800**.

In addition, due to the downwardly-convexed shape of the bottom portion (apex portion) of the base substrate **400** of the semiconductor device **100**, the heat conductive grease (in the vicinity of the center thereof) between the base substrate **400** and the heat dissipation fin **800** can be applied with pressure greater than that applied to the periphery. Therefore, the thickness of the heat conductive grease corresponding to the region below the center of the base substrate **400** can be further reduced, and the heat conductive grease can be spread outward. Owing to the rim portion **520** of the storage region **510**, the spread heat conductive grease can fill up the storage region **510** without leaking to the outside of the storage region **510** and fill the periphery of the base substrate **400**.

When fastening the semiconductor device **100** to the heat dissipation fin **800** using the screws **700**, because the diameter of the screw holes **530** is greater than that of the screws **700**, the screws **700** can reliably be screwed to the heat dissipation fin **800** even when the target positions for the screws **700** on the heat dissipation fin **800** are misaligned.

For comparison of the installation of the heat dissipation fin **800** to the semiconductor device **100**, FIG. **3**B is now used to explain a method for installing the heat dissipation fin to a semiconductor device in which the principal surface **511** of the resin case is not in the concave shape.

The semiconductor device **100***a* is configured by providing the circuit board **300** of the semiconductor device **100** to a resin case **1500** that has one of principal surfaces **511***a* formed flat instead of concave, as shown in FIG. **3**B.

As with the configuration of the semiconductor device **100**, the screws **700** are passed through screw holes **1530** of the resin case **1500** to fasten the heat dissipation fin **800** to the semiconductor device **100***a*. In this case, while the semiconductor device **100***a* receives from the screws **700** a force directed downward in the diagram, the base substrate **400** receives from the heat dissipation fin **800** a force directed upward in the diagram. In the semiconductor device **100***a*, therefore, a force that is directed downward in the diagram acts more on the peripheral portion of the base substrate **400** than on the center of the same.

For this reason, the pressure that can be applied in a downward direction in the diagram to the heat dissipation fin **800** is greater in the semiconductor device **100** than the semiconductor device **100***a*. Thus, in the semiconductor device **100**, a large pressure can be applied to the heat conductive grease below the base substrate **400**, and the heat conductive grease can be spread into a thin layer between the base substrate **400** and the heat dissipation fin **800**.

Such a semiconductor device **100** described above has a semiconductor element **200**, a circuit board **300** having the semiconductor element **200** placed on one of its principal surfaces (the upper side of the diagram), a base substrate **400** placed on the other principal surface of the circuit board **300** (the lower side of the diagram), and a resin case **500** having a storage region **510** with a concave principal surface **511** and an opening **540** and having screw holes **530**. In the semiconductor device **100**, the circuit board **300** is stored in the storage region **510** of the resin case **500** with the base substrate **400** protruding from the concave principal surface **511**, and the stored circuit board **300** (the other principal surface thereof (the upper side of the diagram)) is sealed together with the semiconductor element **200** with sealing resin **550**. The base substrate **400** and the heat dissipation fin **800** are fixed to each other with the heat conductive grease therebetween, and the screw members **700** are inserted into the screw holes **530** of the resin case **500** and screwed to the heat dissipation fin **800**, to fasten the semiconductor device **100** to the heat dissipation fin **800**.

By fastening the semiconductor device **100** to the heat dissipation fin **800** as described above, a force from the resin case **500** is applied to the center of the base substrate **400** in the semiconductor device **100**, with the rim portion **520** of the storage region **510** as a fulcrum, and a force that is directed downward in the diagram acts from the convex base substrate **400** onto the heat dissipation fin **800**. As a result, the heat conductive grease can be spread into a thin layer between the base substrate **400** and the heat dissipation fin **800**, improving the heat dissipation between the base substrate **400** and the heat dissipation fin **800**. Moreover, the heat conductive grease that is spread outside the base substrate **400** fills the periphery of the base substrate **400**. This leads to an increase in air tightness of the periphery of the base substrate **400**, inhibiting bubbles and the like from being mixed therein and preventing the deterioration of the heat dissipation. Heat dissipation of the semiconductor device **100** to which the heat dissipation fin **800** is installed in this manner can be improved.

In addition, shaping the screw holes **530** into a rectangle or an oval can easily make the directions of the force from the resin case **500** to the base substrate **400** in line with each other. A method for producing this semiconductor device **100** is described next with reference to FIGS. **4**A-D.

FIGS. **4**A-D are diagrams for explaining a method for producing the semiconductor device according to the second embodiment. Note that FIG. **4**A is a plan view showing the back of the semiconductor device **100** (the side to which the heat dissipation fin **800** is installed). FIGS. **4**B to **4**D each show the amount of curvature of the resin case **500** of FIG. **4**A at a broken line A-A (upper graphs) and the amount of curvature of the base substrate **400** at a two-dot chain line B-B (lower graphs), which are obtained during the production steps. In each of FIGS. **4**B to **4**D, the vertical axes represent the amounts of curvature [μm], and the horizontal axes the portions of the resin case **500** along the broken line A-A and the base substrate **400** along the broken line B-B.

First, prepared is a resin case **500** measuring approximately 43 mm in width by 26 mm in height by 3.6 mm in thickness, which has screw holes **530** placed at an interval of 36 mm and has already been curved to have a concave principal surface. Next prepared is a circuit board **300** (not shown) measuring approximately 30 mm in width by 13 mm in height, on which is placed a base substrate **400**, also curved beforehand, and to which a semiconductor element **200** is soldered as, for example, a switching element (not shown). The resin case **500** and the circuit board **300** prepared in this manner are combined. In so doing, the base substrate **400** is placed to face the outside toward the storage region **510** of the resin case **500** (to the side where the heat dissipation fin **800** is placed).

In this case, as shown in FIG. **4**B, the maximum amount of curvature of the concave resin case **500** (the amount shown by the arrow in the upper graph) is approximately 153 μm, and the base substrate **400** is also curved in the same direction as the resin case **500** and has the maximum amount of curvature (the amount shown by the arrow in the lower graph) of approximately 23 μm.

Subsequently, the circuit board **300** and the resin case **500** that are installed in this manner are bonded to each other with an adhesive. Note that epoxy resin, silicone resin or the like can be used as the adhesive. In this case, as shown in FIG. **4**C, the maximum amount of curvature of the resin case **500** is approximately 235 μm, and the base substrate **400** is also curved in the same direction as the resin case **500** and has the maximum amount of curvature of approximately 30 μm.

The circuit board **300** that is stored in and adhered to the storage region **510** of the resin case **500** as described above is sealed together with the semiconductor element **200** and an aluminum wire **210** with sealing resin **550** (see FIG. **2**B, for example). The maximum amount of curvature of the resin case **500** at this moment is approximately 126 μm, as shown in FIG. **4**D. The base substrate **400**, on the other hand, is pressed by the sealing resin **550** against the side to which the heat dissipation fin **800** is installed, is thereby curved in the direction opposite to the direction in which the resin case **500** is curved, and has an amount of curvature of approximately 45 μm.

The semiconductor device **100** can easily be produced in which the resin case **500** and the base substrate **400** that are curved in the same direction beforehand are curved in a desired direction during the production steps.

In the foregoing method for producing the semiconductor device **100**, the resin case **500** and the base substrate **400** that are already curved beforehand are provided with desired curvature in the production steps. In addition to such process, it is also possible to form a concave storage region in the resin case **500** and to form the base substrate **400** into a convex shape, and then the resultant base substrate **400** can be placed on the resultant resin case **500** to produce the semiconductor device **100**.

Next, various aspects of the semiconductor device are described with reference to FIGS. **5**A and **5**B. FIGS. **5**A and **5**B are diagrams for explaining another semiconductor device according to the second embodiment. Note that FIG. **5**A is a cross-sectional diagram of a semiconductor device **100***b*. A base substrate **400***a* is the only difference between the semiconductor device **100***b* and the semiconductor device **100**, as shown in FIG. **5**A, but the rest of the configuration is the same as that of the semiconductor device **100**. FIG. **5**B schematically shows the back of a resin case **500***b* of the semiconductor device **100***c*, taken along dashed lines X-X, Y-Y corresponding to those shown in FIG. **2**A.

In the semiconductor device **100**, the level of the apex portion of the base substrate **400** is set in such a manner that the apex portion is accommodated completely in the concave storage region **510** of the resin case **500**, as described above. In the semiconductor device **100***b*, on the other hand, the base substrate **400***a* is not completely accommodated in the storage region **510***a* of the resin case **500**, but the level of the apex portion of the base substrate **400***a* is set such that the apex portion protrudes by approximately several μm from the storage region **510***a*.

As a result of configuring the base substrate **400***a* into this size, the apex portion of the base substrate **400***a* presses the heat conductive grease at the time when the semiconductor device **100***b* is placed on the heat dissipation fin **800**, with the heat conductive grease therebetween. Thereafter, when fastening the semiconductor device **100***b* to the heat dissipation fin **800** using the screws **700**, the heat conductive grease is constantly pressed by the apex portion of the base substrate **400***a* and then stably spreads into a thin layer.

Due to the configuration of the base substrate **400***a* in which the apex portion thereof protrudes by approximately several μm from the storage region **510***a*, the heat conductive grease can stably be spread into a thin layer by fastening the semiconductor device **100***b* to the heat dissipation fin **800**.

Although the base substrate **400** of the semiconductor device **100** is convexed into a mound shape, the base substrate **400** does not have to be shaped into a mound as long as it is convexed. Thus, as shown in FIG. **5**B, for example, the cross section taken along the dashed line X-X may be in a U-shape, and the cross section taken along the dashed line Y-Y may be in a rectangular shape (so-called semi-cylindrical shape).

Screw holes **530***b* in this case may be shaped into a rectangle or an oval that is elongated in the direction of the dashed line X-X. Note that FIG. **5**B shows rectangular screw holes **530***b*. When fastening the heat dissipation fin **800** to the semiconductor device **100***c*, there is a possibility that the heat dissipation fin **800** moves along an outer surface of the base substrate **400***b*. Shaping the screw holes **530***b* into rectangles, therefore, can securely screw the screws **700** to the moving heat dissipation fin **800**. For instance, the basic shape of the screw holes **530***b* is a circle with a diameter of 3.5 mm, which is greater than the diameter of the screws **700** by approximately 0.5 mm, so that the heat dissipation fin **800** can be fastened, the screws **700** having a dimensional tolerance of approximately ±0.3 mm and being of M3 standard. Moreover, in view of the pitch difference of approximately ±0.3 mm between the screw holes **530***b*, it is preferred that the screw holes **530***b* be shaped into an oval that is wider by approximately ±0.5 mm in the pitch direction.

In the situation shown in FIGS. **5**A-B as well, in the semiconductor devices **100***b*, **100***c* fastened to the heat dissipation fin **800** with the screws **700**, the force directed downward in the diagram acts downward from the convex base substrates **400***a*, **400***b* onto the heat dissipation fin **800**, with the rim portion **520** of the storage regions **510**, **510***a* as a fulcrum with respect to the heat dissipation fin **800**, as with the embodiments described above. As a result, the heat conductive grease can be spread into a thinner layer between each of the base substrates **400***a*, **400***b* and the heat dissipation fin **800**, improving the heat dissipation between each of the base substrates **400***a*, **400***b* and the heat dissipation fin **800**. In addition, the heat conductive grease spread to the outside of the base substrates **400***a*, **400***b* fills the peripheries of the base substrates **400***a*, **400***b*. This leads to an increase in air tightness of the peripheries of the base substrates **400***a*, **400***b*, inhibiting bubbles and the like from being mixed therein and preventing the deterioration of the heat dissipation. The heat dissipation of each of the semiconductor devices **100***b*, **100***c* to which the heat dissipation fin **800** is installed in this manner can be improved.

It should be noted that the embodiments described above are to illustrate the specific examples of the present invention. Therefore, the present invention should not be construed as being limited to these embodiments, and various modifications can be made to the present invention without departing from the gist thereof. For example, a circuit layer formed from a metal foil piece (not shown) may be formed on either side of the insulating substrate **310** of the circuit board **300**, wherein a semiconductor element **200** may be bonded to one of the circuit layers, and a metal substrate may be bonded to the other circuit layer.

The above description merely illustrates the principles of the present invention. A person skilled in the art can make various modifications and changes; thus, the present invention is not limited to the precise configurations and applications illustrated and described above. Therefore, all suitable modifications and equivalents are deemed to fall within the scope of the present invention defined by the appended claims and equivalents thereof.

The invention claimed is:

1. A semiconductor device comprising:
a circuit board;
a semiconductor element disposed on a first side of the circuit board;
a metal substrate disposed on a second side of the circuit board;
a storage member having a storage region, a concave principal surface, an opening in which the circuit board is disposed with the metal substrate protruding from the concave principal surface, and fastener holes in the concave principal surface and configured to allow passage of fasteners; and
a heat dissipation member coupled to the storage member via fasteners disposed in the fastener holes such that a first end of the concave principal surface directly contacts the heat dissipation member, a second end of the concave principal surface directly contacts the metal substrate and is spaced apart from the heat dissipation member, and a distance between the metal substrate and the heat dissipation member is less than a distance between the second end of the concave principal surface and the heat dissipation member,
wherein the concave principal surface is configured only by a flat surface or a curved surface and is in direct contact with the metal substrate.

2. The semiconductor device according to claim **1**, wherein the concave principal surface is formed in such a manner that a portion of the storage region outside the fastener holes protrudes in a direction away from the circuit board.

3. The semiconductor device according to claim **2**, wherein the fastener holes face each other with the metal substrate therebetween.

4. The semiconductor device according to claim **1**, wherein the metal substrate has a convex surface that protrudes in a direction away from the circuit board.

5. The semiconductor device according to claim **4**, wherein the metal substrate has a mound shape.

6. The semiconductor device according to claim **4**, wherein the metal substrate has a semi-cylindrical shape.

7. The semiconductor device according to claim **6**, wherein the fastener holes have an oval or rectangular shape in a radial direction and are formed as a pair such that major axes thereof are in line with each other with the metal substrate therebetween.

8. The semiconductor device according to claim **1**, wherein the circuit board is sealed together with the semiconductor element by a resin.

9. The semiconductor device according to claim **1**, further comprising:

a heat conducting material disposed between the heat dissipation member and the metal substrate.

10. The semiconductor device according to claim **9**, wherein the metal substrate protrudes toward the heat dissipation member.

11. The semiconductor device according to claim **1**, wherein distal end points of the storage member protrude in a direction away from the circuit board, and the metal substrate protrudes beyond the distal end points.

12. The semiconductor device according to claim **1**, wherein distal end points of the storage member protrude in a direction away from the circuit board, and the distal end points protrudes beyond the metal substrate.

13. A method for installing a heat dissipation member to a semiconductor device having a semiconductor element,

the semiconductor device comprising:

a circuit board;

a semiconductor element disposed on a first side of the circuit board;

a metal substrate disposed on a second side of the circuit board; and

a storage member having a storage region, a concave principal surface, an opening in which the circuit board is disposed with the metal substrate protruding from the concave

principal surface, and fastener holes in the concave principal surface and configured to allow passage of fasteners,

the method comprising:

arranging a heat dissipation member and the storage member with a heat conductive material therebetween so that the heat dissipation member faces the metal substrate;

inserting the fasteners into the fastener holes; and

coupling the heat dissipation member and the storage member using the fasteners such that a first end of the concave principal surface directly contacts the heat dissipation member, a second end of the concave principal surface directly contacts the metal substrate and is spaced apart from the heat dissipation member, and a distance between the metal substrate and the heat dissipation member is less than a distance between the second end of the concave principal surface and the heat dissipation member,

wherein the concave principal surface is configured only by a flat surface or a curved surface and is in direct contact with the metal substrate.

14. A semiconductor device configured to be disposed on a heat dissipation member, comprising:

a semiconductor element;

a circuit board including a first side on which the semiconductor element is disposed;

a metal substrate disposed on a second side of the circuit board;

a storage member having,

a concave principal surface,

an opening disposed within the concave principal surface, the opening accommodating the circuit board with the metal substrate protruding from the concave principal surface, and

fastener holes disposed in the concave principal surface, the fastener holes being configured to allow passage of the fasteners for fastening the metal substrate to the heat dissipation member disposed facing the metal substrate,

wherein the side surface of the metal substrate is in direct contact with the inside of the concave principal surface, and a rim portion of the concave principal surface protrudes in the same direction as the metal substrate, and

wherein the concave principal surface is configured only by a flat surface or a curved surface and is in direct contact with the metal substrate.

15. The semiconductor device according to claim **14**, wherein the rim portion is disposed outside of the fastener holes.

16. The semiconductor device according to claim **15**, wherein the end of the rim portion protrudes.

17. The semiconductor device according to claim **14**, wherein the storage member further includes a principal surface facing the concave principal surface, and the concave principal surface is inclined with respect to the principal surface of the storage member.

18. The semiconductor device according to claim **17**, wherein the concave principal surface is configured only by the flat surface.

19. The semiconductor device according to claim **17**, wherein the concave principal surface is configured only by the curved surface.

20. A semiconductor device configured to be disposed on a heat dissipation member, comprising:

a semiconductor element;

a circuit board including a first side on which the semiconductor element is disposed;

a metal substrate disposed on a second side of the circuit board;

a storage member having,

a concave principal surface,

an opening disposed within the concave principal surface, the opening accommodating the circuit board with the metal substrate protruding from the concave principal surface, and

fastener holes disposed in the concave principal surface, the fastener holes being configured to allow passage of the fasteners for fastening the metal substrate to the heat dissipation member disposed facing the metal substrate,

wherein the side surface of the metal substrate is in direct contact with the inside of the concave principal surface, and a rim portion of the concave principal surface protrudes in the same direction as the metal substrate,

wherein the storage member further includes a principal surface facing the concave principal surface, and the concave principal surface is inclined with respect to the principal surface of the storage member,

wherein the concave principal surface is configured by a flat surface or a curved surface, and

wherein the axes of the fastener holes are substantially perpendicular to the concave principal surface.

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